

(12) PATENT
(19) AUSTRALIAN PATENT OFFICE

(11) Application No. AU 199867281 B2
(10) Patent No. 743140

(54) Title
Peristaltic pump

(51)⁶ International Patent Classification(s)
A61M 005/142 F04B 043/08

(21) Application No: 199867281 (22) Application Date: 1998 .02 .24

(87) WIPO No: W098/47551

(30) Priority Data

(31) Number	(32) Date	(33) Country
120697	1997 .04 .18	IL
97202451	1997 .08 .07	EP

(43) Publication Date : 1998 .11 .13
(43) Publication Journal Date : 1999 .01 .07
(44) Accepted Journal Date : 2002 .01 .17

(71) Applicant(s)
Societe Des Produits Nestle S.A.

(72) Inventor(s)
Swi Barak

(74) Agent/Attorney
BALDWIN SHELSTON WATERS,Level 21,60 Margaret Street,SYDNEY NSW 2000

(56) Related Art
EP 0526962
GB 2071222
US 4869646

BEST AVAILABLE COPY

100-443887-100

CT)

A1

(11) International Publication Number:

WO 98/47551

(43) International Publication Date: 29 October 1998 (29.10.98)

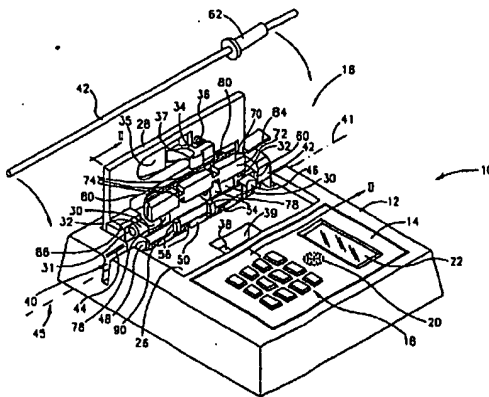
(81) Designated States: AU, BR, CA, CN, ID, JP, MX, RU, VN,
European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB,
GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

Published

With international search report.

(54) Title: PERISTALTIC PUMP



(57) Abstract

A peristaltic pump for propelling liquid through a flexible tube segment. The pump has a cam shaft which carries a plurality of cams each having a driving surface. The driving surfaces of adjacent cams are spaced at an angle to each other about the cam shaft. The pump also has a plurality of cam followers which are each reciprocal in a common direction perpendicular to the axis of the cam shaft. Each cam follower has a cam surface riding on the driving surface of a cam and a tube engaging surface for engaging the flexible tube segment. At least one of the cam followers is a restriction cam follower of which the tube engaging surface engages the flexible tube segment for a longer period than that of the other cam followers. The pump also has a motor for rotating the cam shaft whereby the cams cause the cam followers to each engage and occlude the flexible tube segment to form a propagating depression wave in the flexible tube segment for propelling liquid. The restriction cam followers prevent back flow of the liquid.

Peristaltic Pump

This invention relates to a peristaltic pump which is suitable for use in systems for administration of liquids to a patient.

5 Systems for administration of liquids to a patient are widely known. The manner of propelling the liquid to the patient may be by gravitation, by means of pressure applied on a deformable container, or by means of a pump. In pump-operated administration systems, the pump must be capable of administering the liquid in a controlled, continuous manner. A particular example of a pump used in pump-operated administration systems is a peristaltic pump. However, peristaltic pumps are subject to
10 back flow problems.

Therefore there is a need for a peristaltic pump which is able to administer the liquid in a controlled, continuous manner without back flow of liquid.

It is an object of the present invention to overcome or ameliorate at least one of the disadvantages of the prior art, or to provide a useful alternative.

15 This invention provides a peristaltic pump for propelling liquid through a flexible tube segment, the pump comprising:

a cam shaft carrying a plurality of cams each having a driving surface, the driving surfaces of adjacent cams being spaced at an angle to each other about the cam shaft;

20 a plurality of cam followers which are each reciprocal in a common direction perpendicular to the axis of the cam shaft, each cam follower having a cam surface riding on the driving surface of a cam and a tube engaging surface for engaging the flexible tube segment, at least one of the cam followers being a restriction cam follower of which the tube engaging surface engages the flexible tube segment for a longer period than that of the other cams; and

25 a motor for rotating the cam shaft whereby the cams cause the cam followers to each engage and occlude the flexible tube segment to form a propagating depression wave in the flexible tube segment for propelling liquid; the restriction cam followers preventing back flow of the liquid.



Unless the context clearly requires otherwise, throughout the description and the claims, the words 'comprise', 'comprising', and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of "including, but not limited to".

5 Preferably the tube engaging surfaces of the restriction cam followers extend further from the cams than the tube engaging surfaces of the other cam followers. This may be provided by providing the tube engaging surface of each restriction cam follower with a planar tube engaging surface while the other cam followers have a concave tube engaging surface.

10 A restriction cam follower is preferably mounted as the terminal cam follower; especially as the terminal cam follower in forward pumping direction of the pump.

2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000
1001
1002
1003
1004
1005
1006
1007
1008
1009
1010
1011
1012
1013
1014
1015
1016
1017
1018
1019
1020
1021
1022
1023
1024
1025
1026
1027
1028
1029
1030
1031
1032
1033
1034
1035
1036
1037
1038
1039
1040
1041
1042
1043
1044
1045
1046
1047
1048
1049
1050
1051
1052
1053
1054
1055
1056
1057
1058
1059
1060
1061
1062
1063
1064
1065
1066
1067
1068
1069
1070
1071
1072
1073
1074
1075
1076
1077
1078
1079
1080
1081
1082
1083
1084
1085
1086
1087
1088
1089
1090
1091
1092
1093
1094
1095
1096
1097
1098
1099
1100
1101
1102
1103
1104
1105
1106
1107
1108
1109
1110
1111
1112
1113
1114
1115
1116
1117
1118
1119
1120
1121
1122
1123
1124
1125
1126
1127
1128
1129
1130
1131
1132
1133
1134
1135
1136
1137
1138
1139
1140
1141
1142
1143
1144
1145
1146
1147
1148
1149
1150
1151
1152
1153
1154
1155
1156
1157
1158
1159
1160
1161
1162
1163
1164
1165
1166
1167
1168
1169
1170
1171
1172
1173
1174
1175
1176
1177
1178
1179
1180
1181
1182
1183
1184
1185
1186
1187
1188
1189
1190
1191
1192
1193
1194
1195
1196
1197
1198
1199
1200
1201
1202
1203
1204
1205
1206
1207
1208
1209
1210
1211
1212
1213
1214
1215
1216
1217
1218
1219
1220
1221
1222
1223
1224
1225
1226
1227
1228
1229
1230
1231
1232
1233
1234
1235
1236
1237
1238
1239
1240
1241
1242
1243
1244
1245
1246
1247
1248
1249
1250
1251
1252
1253
1254
1255
1256
1257
1258
1259
1260
1261
1262
1263
1264
1265
1266
1267
1268
1269
1270
1271
1272
1273
1274
1275
1276
1277
1278
1279
1280
1281
1282
1283
1284
1285
1286
1287
1288
1289
1290
1291
1292
1293
1294
1295
1296
1297
1298
1299
1300
1301
1302
1303
1304
1305
1306
1307
1308
1309
1310
1311
1312
1313
1314
1315
1316
1317
1318
1319
1320
1321
1322
1323
1324
1325
1326
1327
1328
1329
1330
1331
1332
1333
1334
1335
1336
1337
1338
1339
1340
1341
1342
1343
1344
1345
1346
1347
1348
1349
1350
1351
1352
1353
1354
1355
1356
1357
1358
1359
1360
1361
1362
1363
1364
1365
1366
1367
1368
1369
1370
1371
1372
1373
1374
1375
1376
1377
1378
1379
1380
1381
1382
1383
1384
1385
1386
1387
1388
1389
1390
1391
1392
1393
1394
1395
1396
1397
1398
1399
1400
1401
1402
1403
1404
1405
1406
1407
1408
1409
1410
1411
1412
1413
1414
1415
1416
1417
1418
1419
1420
1421
1422
1423
1424
1425
1426
1427
1428
1429
1430
1431
1432
1433
1434
1435
1436
1437
1438
1439
1440
1441
1442
1443
1444
1445
1446
1447
1448
1449
1450
1451
1452
1453
1454
1455
1456
1457
1458
1459
1460
1461
1462
1463
1464
1465
1466
1467
1468
1469
1470
1471
1472
1473
1474
1475
1476
1477
1478
1479
1480
1481
1482
1483
1484
1485
1486
1487
1488
1489
1490
1491
1492
1493
1494
1495
1496
1497
1498
1499
1500
1501
1502
1503
1504
1505
1506
1507
1508
1509
1510
1511
1512
1513
1514
1515
1516
1517
1518
1519
1520
1521
1522
1523
1524
1525
1526
1527
1528
1529
1530
1531
1532
1533
1534
1535
1536
1537
1538
1539
1540
1541
1542
1543
1544
1545
1546
1547
1548
1549
1550
1551
1552
1553
1554
1555
1556
1557
1558
1559
1560
1561
1562
1563
1564
1565
1566
1567
1568
1569
1570
1571
1572
1573
1574
1575
1576
1577
1578
1579
1580
1581
1582
1583
1584
1585
1586
1587
1588
1589
1590
1591
1592
1593
1594
1595
1596
1597
1598
1599
1600
1601
1602
1603
1604
1605
1606
1607
1608
1609
1610
1611
1612
1613
1614
1615
1616
1617
1618
1619
1620
1621
1622
1623
1624
1625
1626
1627
1628
1629
1630
1631
1632
1633
1634
1635
1636
1637
1638
1639
1640
1641
1642
1643
1644
1645
1646
1647
1648
1649
1650
1651
1652
1653
1654
1655
1656
1657
1658
1659
1660
1661
1662
1663
1664
1665
1666
1667
1668
1669
1670
1671
1672
1673
1674
1675
1676
1677
1678
1679
1680
1681
1682
1683
1684
1685
1686
1687
1688
1689
1690
1691
1692
1693
1694
1695
1696
1697
1698
1699
1700
1701
1702
1703
1704
1705
1706
1707
1708
1709
1710
1711
1712
1713
1714
1715
1716
1717
1718
1719
1720
1721
1722
1723
1724
1725
1726
1727
1728
1729
1730
1731
1732
1733
1734
1735
1736
1737
1738
1739
1740
1741
1742
1743
1744
1745
1746
1747
1748
1749
1750
1751
1752
1753
1754
1755
1756
1757
1758
1759
1760
1761
1762
1763
1764
1765
1766
1767
1768
1769
1770
1771
1772
1773
1774
1775
1776
1777
1778
1779
1780
1781
1782
1783
1784
1785
1786
1787
1788
1789
1790
1791
1792
1793
1794
1795
1796
1797
1798
1799
1800
1801
1802
1803
1804
1805
1806
1807
1808
1809
1810
1811
1812
1813
1814
1815
1816
1817
1818
1819
1820
1821
1822
1823
1824
1825
1826
1827
1828
1829
1830
1831
1832
1833
1834
1835
1836
1837
1838
1839
1840
1841
1842
1843
1844
1845
1846
1847
1848
1849
1850
1851
1852
1853
1854
1855
1856
1857
1858
1859
1860
1861
1862
1863
1864
1865
1866
1867
1868
1869
1870
1871
1872
1873
1874
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2045
2046
2047
2048
2049
2050
2051
2052
2053
2054
2055
2056
2057
2058
2059
2060
2061
2062
2063
2064
2065
2066
2067
2068
2069
2070
2071
2072
2073
2074
2075
2076
2077
2078
2079
2080
2081
2082
2083
2084
2085
2086
2087
2088
2089
2090
2091
2092
2093
2094
2095
2096
2097
2098
2099
2100
2101
2102
2103
2104
2105
2106
2107
2108
2109
2110
2111
2112
2113
2114
2115
2116
2117
2118
2119
2120
2121
2122
2123
2124
2125
2126
2127
2128
2129
2130
2131
2132
2133
2134
2135
2136
2137
2138
2139
2140
2141
2142
2143
2144
2145
2146
2147
2148
2149
2150
2151
2152
2153
2154
2155
2156
2157
2158
2159
2160
2161
2162
2163
2164
2165
2166
2167
2168
2169
2170
2171
2172
2173
2174
2175
2176
2177
2178
2179
2180
2181
2182
2183
2184
2185
2186
2187
2188
2189
2190
2191
2192
2193
2194
2195
21

The restriction cam follower preferably retracts to open the flexible tube segment only when the rear terminal cam follower is fully extended.

Preferably the pump further comprises sensor means for determining the direction and speed of rotation of the cam shaft. The sensor means may comprise

5 a disc which rotates in accordance with the cam shaft, the disc having a plurality of substantially identical apertures through it equally spaced about its axis; and

10 a pair of sensors mounted adjacent the disc in alignment with the apertures, the sensors being able to determine whether both sensors are aligned in with the same aperture, one sensor is aligned with an aperture but the other is not; and both sensors are not aligned with an aperture, the direction and speed of rotation of the disc being computable from this information.

Each cam is preferably aligned at an angle of 30° with respect to its adjacent cams. Twelve cams may be provided.

15 The pump may further comprise a housing having a chamber through which the tube segment extends and into which the cam followers reciprocally extend, the chamber having a removable wall element which retains the tube segment between it and the tube engaging surfaces of the cam followers.

20 The motor preferably may rotate the shaft clockwise and counter-clockwise, enabling liquid to be propelled through the tube segment in both directions.

The cam followers are preferably arranged in a linear array on the shaft and are arranged so that revolution of the cam shaft causes a phase shift in the reciprocation of the cam followers along the linear array. Consequently, the
25 occlusion "advances" in the tube segment from one tube portion to the next, in a continuous wave-like manner. This propels the liquid through the tube segment and hence to the patient through a liquid flow set.

The pump preferably comprises one or more sensors for measurement of flow parameters or parameters indicative of the pressure within the tube
30 segment. An example of a suitable sensor is a pressure sensor which measures the diameter of the tube segment (which is an indication of the liquid pressure within the tube segment). A particular example of such a pressure sensor is a strain gauge. The determination of the pressure may be important in order to determine existence of flow problems such as, for example, an occlusion in the
35 flow set, and the presence of leaks. Another example of a suitable sensor may be a sensor which tests for existence of air pockets or foam within the tube segment.

A particular example of such a sensor is an ultrasonic sensor which measures the attenuation of an ultrasonic signal passing through the tube segment, which is different for liquid or gas. The sensors may be coupled to the control unit for the pump and upon detecting a faulty flow parameter or existence of air pockets or foam, the control unit may be induced to halt the pump, and optionally also to generate an alarm signal.

Embodiments of the invention are now described, by way of example only, with reference to the drawings in which:

Fig. 1 is a front isometric view of a pump with the receptacle door being open prior to engagement with a tube segment of a flow set,

Fig. 2 shows a partial cross-section through lines II-II in Fig. 1, with the door closed and a tube segment in the receptacle;

Fig. 3 is a rear isometric view of the pump, with the cover removed to show the internal components;

Fig. 4 shows, in isolation, the metal support structure holding the electric motor and the cam shaft, with some of the cams removed, to reveal the shaft;

Fig. 5 is an isometric view of a segment of the cam shaft with several cams thereon illustrating the angular diversion between neighbouring cams;

Fig. 6A and 6B show axial views of two kinds of cams differing from one another in the angular orientation of the shaft recessing bore;

Fig. 7 shows, in isolation, two cam followers, where

Fig. 7A shows a cam follower with a concave tube engaging surface, and

Fig. 7B shows a terminal cam follower with a flat tube engaging surface;

Fig. 8 is a schematic representation showing a side view of two different cam followers, both in two operational states, where

Fig. 8A shows the cam followers in an extended position where they press and occlude a tube segment, and

Fig. 8B shows the cam followers in a retracted position disengaged from the tube segment so as to fully open the bore to allow flow of liquid therethrough; and

Fig. 9 is a side view showing the cam shaft with the cams mounted thereon, the cam followers and the tube segment, in isolation, in continuous consecutive phases of the pump's operation.

Referring to the drawings, a pump 10 comprises a housing 12 which has a user interface unit 14 and a pumping assembly 16. The user interface 14 has a key pad 18, an audio signalling element 20, and a display 22. The key pad 18

may be used to initiate or stop the pump and for input of data such as flow rate, flow time, and the like. The audio signalling element 20 is typically a small loudspeaker for providing alarm signals.

5 The pumping assembly 16 is positioned in a rectangular basin 26 in the housing 12 and includes a motor support structure 33 and a door 28 which closes the opening of the basin 26. The door 28 is hingedly connected to the motor support structure 33 by pivoting members 30, pivots 31 and hinge elements 32. The pivoting members 30 are integral with the door 28 and are connected by the pivots 31 to the hinge elements 32 which are integral with the motor support
10 structure 33. The hinge elements 32 are situated at an end of a projection 32' of the motor support structure 33. The door 28 also includes a latch 34 having a release lever 35, a biasing spring 36 and a hook 37. The hook 37 engages with a lateral shoulder 38 of a locking recess 39 in the housing 12 to lock the door 28 closed on the housing 12.

15 A channel 40 for receiving a flexible tube segment 42 of a flow set (not shown) extends across the housing 12, between a pair of openings 42 and 44 in the side walls of the housing 12. The channel 40 defines a first axis 45. The channel 40 has a pair of well-shaped portions 46 and 48 at either end which are separated by a primary channel portion 50. The primary channel portion 50 of
20 the channel 40 has two pairs of opposing tube centralising segments 54 and 56. Adjacent one opening 42, the channel 40 has a cavity 60, which together with the opening 42, serves as a socket for receiving a shaped connector 62 coupled in tube segment 42. The fitting of the shaped connector 62 into the socket ensures correct engagement of the tube segment 42 with the pump 10. Further, the cavity
25 60 may include a microswitch (not shown) to provide a signal to the control unit of the pump 10 indicative of engagement of the tube segment 42 with the pump 10.

Further the door 32 includes a pair of projections 84 and 86 which, while door 32 is being closed, assist in pushing the tube segment 42 tightly into the
30 channel 40.

A wall element 70 is pivotally coupled to the pivots 31 by pivoting members 78. The wall element 70 has a planar, tube engaging face 72 and has two pairs of recesses 74 in correspondence to centralising segments 54 and 56. The wall element 70 is coupled to the door 32 by means of biasing springs 80,
35 whereby closing of the door 32 imparts a biasing force on the wall element 70.

Each well-shaped portion 46 and 48 has, at its bottom surface (not shown) a sensor. One of the sensors is an ultrasonic sensor to detect the constituents of the liquid passing through the tube segment 42, in particular to determine whether it contains bubbles or air pockets. The other sensor is a strain gauge for measuring the diameter of the tube segment 42 to determine the pressure of the liquid within the tube segment 42. Any suitable sensors may be used. Suitable sensors are known.

The bottom surface of primary channel portion 50 of the channel 40 is lined with a fabric 90. Therefore, once the tube segment 42 is placed into the channel 40 and the door 32 is closed, the tube segment 42 is retained between the tube engaging face 72 of the wall element 70 and the fabric 90 (see Fig. 2). The fabric 90 may be plastic film or the like. The fabric 90 serves to protect the tube segment 42 against wear and tear.

The pumping mechanism of the pump 10 is formed of a plurality of cams 100 and cam followers 94; the embodiment shown having twelve. As best seen in Figs. 2 and 7, the cam followers 94 have a tube engaging surface 96 at one end and a cam surface 98 at their opposite end. The cam surface 98 of each cam follower 94 bears on a cam 100. Certain of the cam followers 94 have a concave tube engaging surface 96 which serves to centralise the tube segment 42 within the chamber 40. This prevents distortions in the linear arrangement of the tube segment 42.

Each cam 100 is eccentrically fixed on a hexagonal shaft 102 which lies in an axis parallel to the first axis 45. Due to the eccentric arrangement of the cams 100 on the hexagonal shaft 102, when the cams 100 rotate with the shaft 102, they induce the cam followers 94 to reciprocate linearly in a direction 106 normal to the first axis 45. During this reciprocal movement, the cam followers 94 move between a first, extended position where they depress a portion of tube segment 42 to occlusion, and a second, retracted position (as shown in Fig. 2), where the bore 43 of the tube segment 42 is open to allow liquid flow.

As best illustrated in Fig. 6, each cam 100 has a hexagonal bore 140 into which the hexagonal shaft 102 is received. Further each cam 100 has a crescent-shaped recess 142 in each face. A cylindrical bore 144 extends through each cam 100, from the recess 142 in one face to the recess 142 in the other face. A cylindrical pin 146 projects outwardly from one face of the cam 100 from within the recess 142. The angle between the cylindrical bore 144 and the cylindrical pin 146 on the face, measured from the centre of bore 140, is 30°.

The cams 100 are provided in two different configurations. One configuration is illustrated as cam 100' in Figs. 6A. In this configuration, the crescent-shaped recess 142 is centrally aligned above a side of the hexagonal bore 140. The other configuration is illustrated as cam 100" in Fig. 6B. In this configuration, the crescent-shaped recess 142 is centrally aligned above an apex of the hexagonal bore 142. Hence the two configurations differ from one another in the relative orientation of the hexagonal bore 144 with respect to the remainder of the cam 100, the difference in orientation being 30°.

The cams 100 are mounted on the hexagonal shaft 102 such that a cam 100' of one configuration is followed by a cam 100" of the other configuration. In this way, adjacent cams 100 are aligned at an angle of 30° with respect to one another. When mounted on the hexagonal shaft 102, the cylindrical pin 146 projecting from one cam 100' fits into the cylindrical bore 144 of the adjacent cam 100". In this way, a linear array of cams 100 is obtained, with each cam 100 aligned at an angle of 30° from any adjacent cam 100. The sum of the angles between all twelve cams 100, namely between the first cam 100 in the array and the last one, is 330°. This means that there is a phase difference of 30° in the reciprocation cycle of the cam follower 94 at one end and that at the other end.

As can be best seen in Fig. 3, the cam surfaces 98 of the cam followers 94 protrude through openings 112 in the motor support structure 33 towards the cams 100. The cams 100 are arranged in three groups of four cams each, each group corresponding to one of the openings 112. The three groups are separated from one another by spacer elements 111.

Each spacer element 111 has a cylindrical bore at one end for receiving a cylindrical pin 146 projecting from the adjacent cam 100. Also, each spacer element 111 is provided with a cylindrical pin (not shown) at an opposite end for engaging in the cylindrical bore 144 of a cam 100 at that end. A ring (not shown) is mounted at both ends of the array of cams 100 to hold the cams 100 in position on the hexagonal shaft 102. The ring at one end has a cylindrical pin for engaging in the cylindrical bore 144 of the adjacent cam 100 and the ring at the other end has a cylindrical bore for receiving the cylindrical pin 146 of its adjacent cam 100.

One of the cam followers, a restriction cam follower 94', illustrated in Fig. 7B, extends further, in its extended position, towards the tube segment 42 as compared to the other cam followers 94. This may be provided in a number of ways. For example, the restriction cam follower 94' may be slightly longer than

the other cam followers 94. Alternatively, if the cam followers 94 have a concave tube engaging surface 96, the restriction cam follower 94' may be provided with a straight or convex tube engaging surface 96'. In the case where the restriction cam follower 94' is provided with a straight tube engaging surface 96', the overall length of the restriction cam follower 94' is the same as that of all the other cam followers 94. If all cam followers 94 were identical, the tube segment 42 at the front cam follower 94 would open prior to complete occlusion of the tube segment 42 at the rear cam follower 94. This would result in a small degree of back flow of fluid in the small time interval prior to complete occlusion of the tube segment 42 at the rear cam follower 94. However, by providing a restriction cam follower 94', this problem may be avoided. Ordinarily the pump 10 has one pumping direction which is defined as the forward pumping direction. The restriction cam follower 94' is preferably positioned as the forward terminal cam follower.

The fully extended and fully retracted position of a standard cam follower 94 and a restriction cam follower 94' are illustrated in Figs. 8A and 8B. Fig. 8A illustrates both types of cam follower 94 and 94' in their fully extended position in which they occlude a portion of the tube segment 42 through the intermediary of the fabric 90. In the case of the standard cam follower 94, the saddle 148 of the tube engaging surface 96 engages the tube segment 42. Because the restriction cam follower 94' has a planar tube engaging surface 96', the tube engaging surface 96' extends further towards wall 72 and thus squeezes the tube segment 42 to a greater extent as compared to the standard cam follower 94. Both types of cam follower 94 and 94' are illustrated in Fig. 8B in their fully retracted position with the tube segment 42 fully opened to allow flow of liquid through its bore 43.

An electric motor 108 is fixed on the motor support structure. This can best be seen in Fig. 4. The electric motor 108 has a gear wheel 120 coupled to a gear wheel 122 on the hexagonal shaft 102. The motor 108 is connected to a control unit 136 through a cable 138.

An encoder wheel 124 is fixed onto the end of the hexagonal shaft 102. The encoder wheel 124 has a plurality of openings 126 through it and arranged in a circle about the centre of the encoder wheel 124. Each opening 126 is of exactly the same size and shape as each other opening 126. Further, each opening 126 is positioned a distance from the centre of the encoder wheel 124 equal to that of any other opening 126. Also, the angle between any pair of

openings 126 is the same as that between any other pair of openings such that the openings 126 are equi-spaced around the centre of the encoder wheel 124. The arc distance between each pair of openings 126 is approximately the same as the arc dimension of each opening 126.

5 A pair of optical sensors 130 are fixed to the motor support structure 33 in close proximity to the encoder wheel 124 and to each other. The optical sensors 130 are aligned with the openings 126 such that they may determine whether there is an opening 126 in front of them or not. Further, the distance between the optical sensors 130 is such that both sensors may be aligned in front of an
10 opening 126 or in front of the area between a pair of openings 126.

At any point in the rotation of the encoder wheel 124, four possible situations exist. First, both sensors may be in front of an opening 126. Secondly, the first sensor may be in front of an opening 126 while the second is in front of the area between two openings 126. Thirdly, the second sensor may be in front
15 of an opening 126 while the first is in front of the area between two openings 126. Finally, both sensors may be in front of the area between two openings 126. Hence the sensors 130 may be used to monitor the direction and speed of rotation of the openings 126 and hence may be used to determine the direction and speed of rotation of the pump 10. From this, the direction of flow and the flow rate of
20 the liquid through the tube segment 42 may be determined.

The sensors 130 are preferably controlled such that, if one sensor is not working, the other sensor 130 will not function. This prevents mis-counting problems which may arise if only one sensor 130 were operating.

Fig. 9 shows three continuous consecutive phases of the operation of the
25 pump 10. As the cam shaft 102 and the cams 100 turn, the point of occlusion of the tube segment 42 advances from left 150 (Fig. 9A) towards the middle of the segment 152 (Fig. 9B) and to the right 154 (Fig. 9C) in a wave-like fashion. This sequence is repeated continuously and thus a body of liquid is continuously propelled from left to right. The restriction cam follower 94' is typically the right
30 most one. Since it extends further in its extended position, it occludes the tube segment 42 for somewhat longer than the other cam followers 94. This prevents back flow of liquid.

Numerous modifications may be made to the embodiments described above without departing from the scope of the invention. For example, it is not
35 necessary to use twelve cams 100; any suitable number of cams 100 may be used. Also, it is not necessary to use a hexagonal shaft 102. Instead a shaft of

any suitable cross-section may be used. For example, if a shaft 102 of octagonal cross-section is used, adjacent cams 100 will be aligned at an angle of about 22.5° with respect to each other. In this case, the total number of cam 100 will conveniently be 16. Further, the cams 100 need not be mounted on the shaft 102 in groups of 4.

5 Further, the embodiment described causes a single propagating depression in the tube segment. However, this is not essential and the cams 100 may be arranged to cause the depression wave to have more than one cycle.

Although the invention has been described with reference to specific examples it will be appreciated to those skilled in the art that the invention may be embodied in
10 many other forms.

DE
R
N



Claims

1. A peristaltic pump for propelling liquid through a flexible tube segment, the pump comprising:
 - 5 a cam shaft carrying a plurality of cams each having a driving surface, the driving surfaces of adjacent cams being spaced at an angle to each other about the cam shaft;
 - a plurality of cam followers which are each reciprocal in a common direction perpendicular to the axis of the cam shaft, each cam follower having a cam surface riding on the driving surface of a cam and a tube engaging surface for engaging the flexible tube segment, at least one of the cam followers being a restriction cam follower of which the tube engaging surface engages the flexible tube segment for a longer period than that of the other cam followers; and
 - 10 a motor for rotating the cam shaft whereby the cams cause the cam followers to each engage and occlude the flexible tube segment to form a propagating depression wave in the flexible tube segment for propelling liquid; the restriction cam followers preventing back flow of the liquid.
2. A pump according to claim 1 in which the tube engaging surfaces of the restriction cam followers extend further from the cams than the tube engaging surfaces of the other cam followers.
3. A pump according to claim 2 in which the tube engaging surfaces of the restriction cam followers have a planar tube engaging surface while the other cam followers have a concave tube engaging surface.
4. A pump according to any of claims 1 to 3 in which a restriction cam follower is mounted as a terminal cam follower.
5. A pump according to claim 4 in which the restriction cam follower is mounted as the terminal cam follower in forward pumping direction of the pump.
6. A pump according to Claim 5 in which the terminal cam follower retracts to open the flexible tube segment only when the rear terminal cam follower is fully extended.

7. A pump according to any of claims 1 to 6 further comprising sensor means for determining the direction and speed of rotation of the cam shaft.

8. A pump according to claim 7 in which the sensor means comprises:

5 a disc which rotates in accordance with the cam shaft, the disc having a plurality of substantially identical apertures through it equally spaced about its axis; and
a pair of sensors mounted adjacent the disc in alignment with the apertures, the sensors being able to determine at any point in time whether both sensors are aligned with the same aperture, one sensor is aligned with an aperture but the other is not; or both sensors are not aligned with an aperture; monitoring of the changes in alignment of
10 the sensors with the apertures enabling the direction and speed of rotation of the disc to be computed.

9. A pump according to any one of claims 1 to 8 in which each cam is aligned at an angle of 30° with respect to its adjacent cams.

10. A pump according to any one of claims 1 to 9 in further comprising a housing
15 having a chamber through which the tube segment extends and into which the cam followers reciprocally extend, the chamber having a removable wall element which retains the tube segment between it and the tube engaging surfaces of the cam followers.

11. A peristaltic pump for propelling liquid through a flexible tube substantially as
20 here described with reference to any one of the embodiments of the invention illustrated in the accompanying drawings.

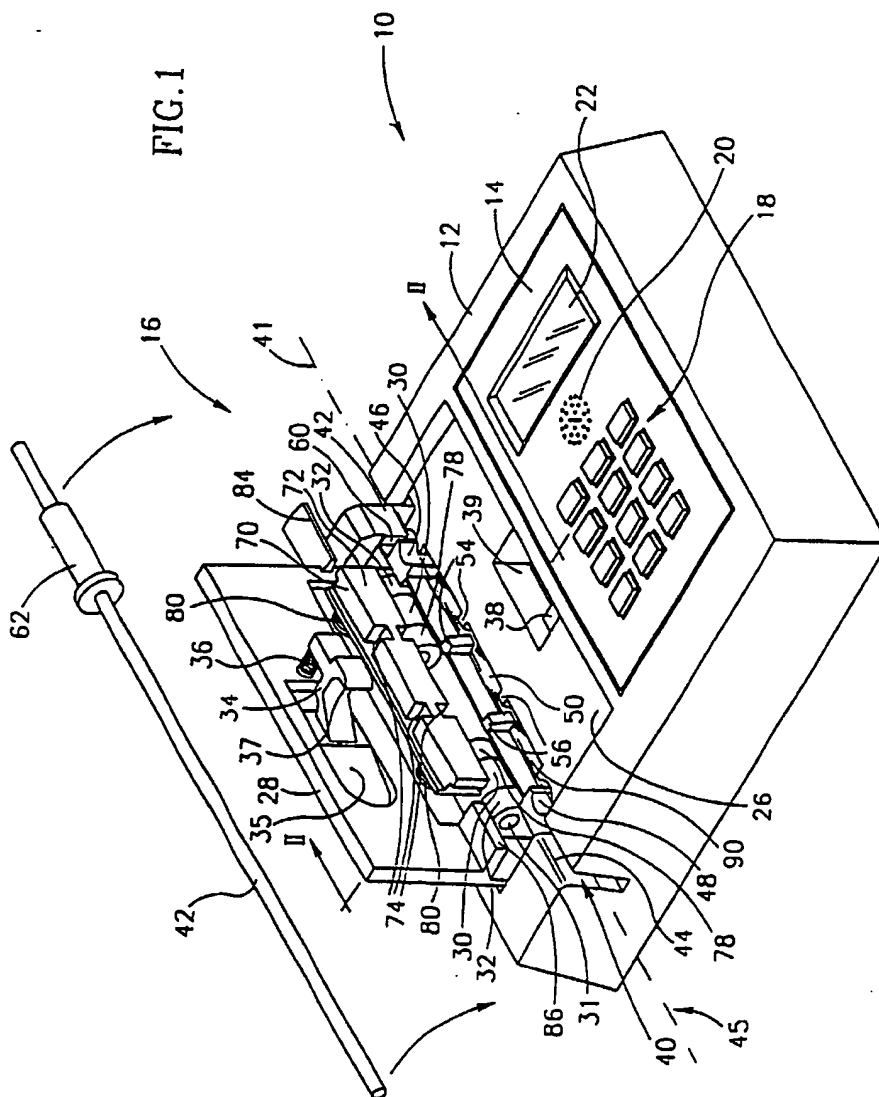
DATED this 23rd Day of May, 2000

SOCIETE DES PRODUITS NESTLE S.A.

25 Attorney: JOHN D. FORSTER
Fellow Institute of Patent and Trade Mark Attorneys of Australia
of BALDWIN SHELSTON WATERS



FIG. 1



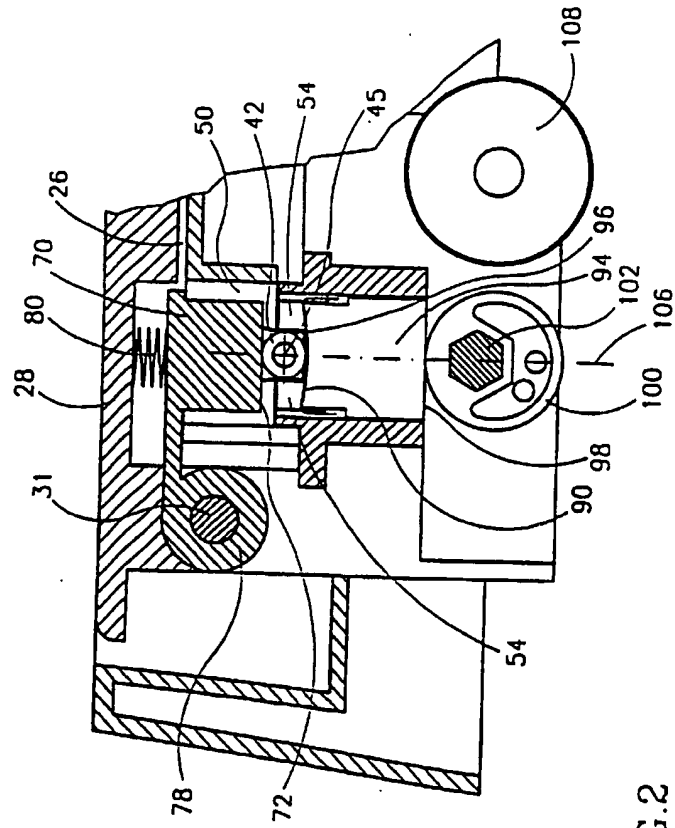


FIG. 2

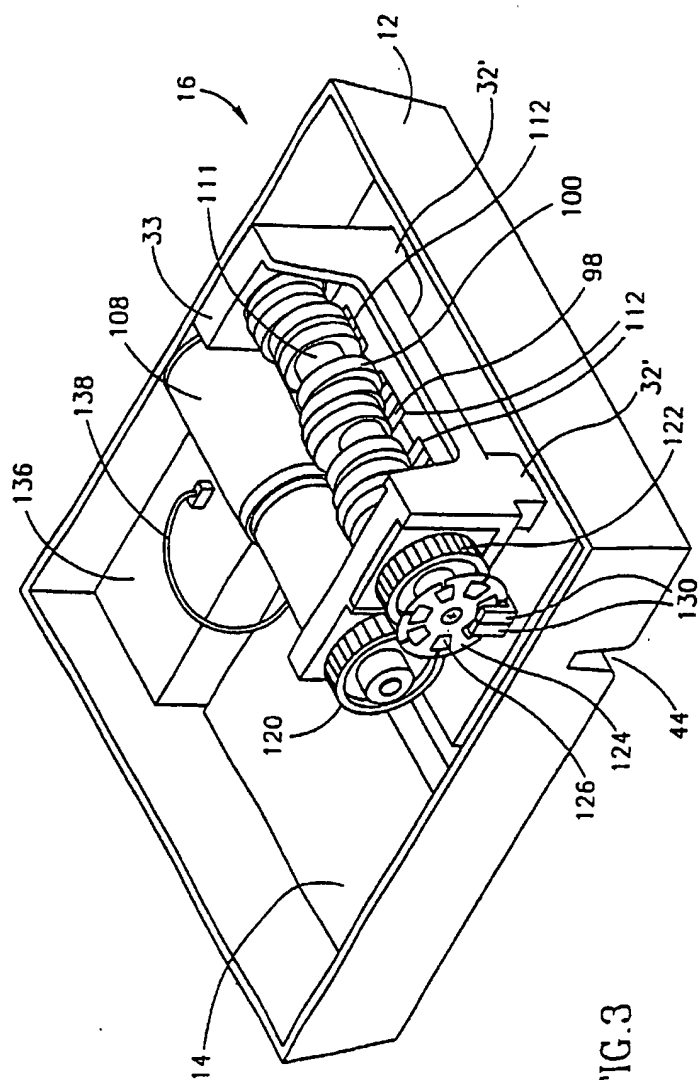


FIG. 3

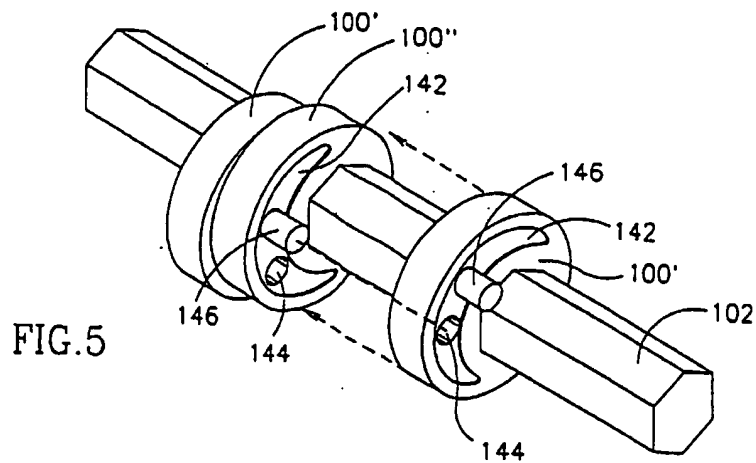


FIG. 5

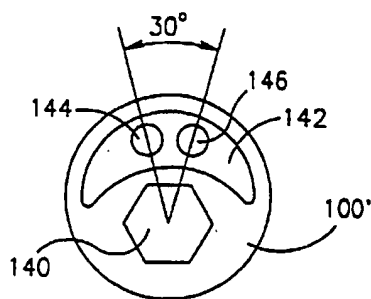


FIG. 6A

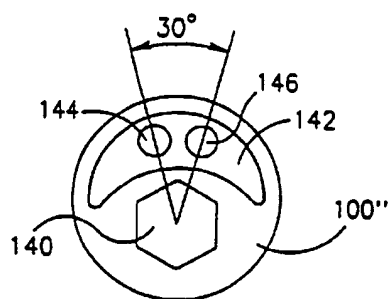


FIG. 6B

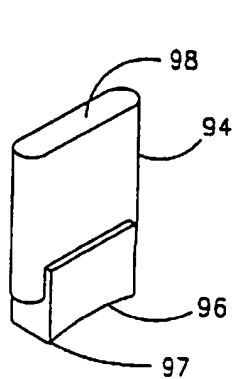


FIG. 7A

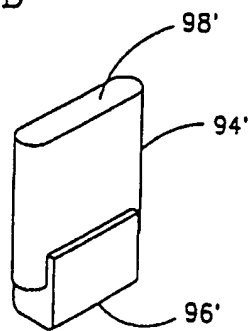


FIG. 7B

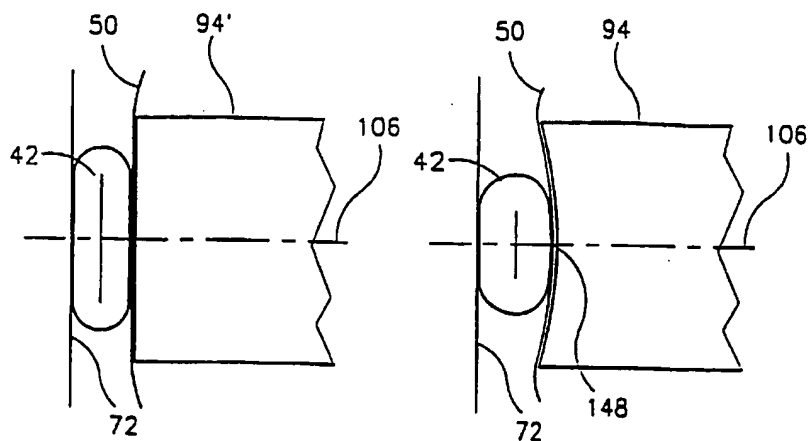


FIG. 8A

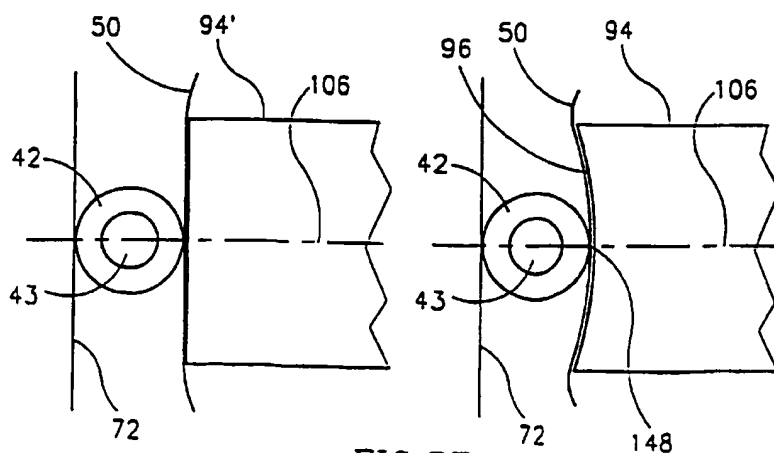
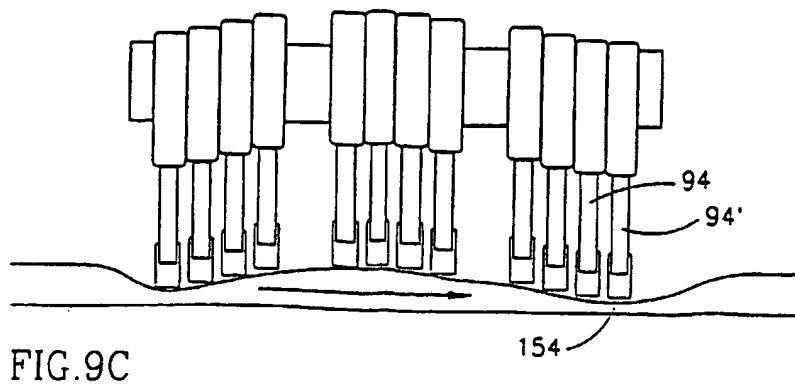
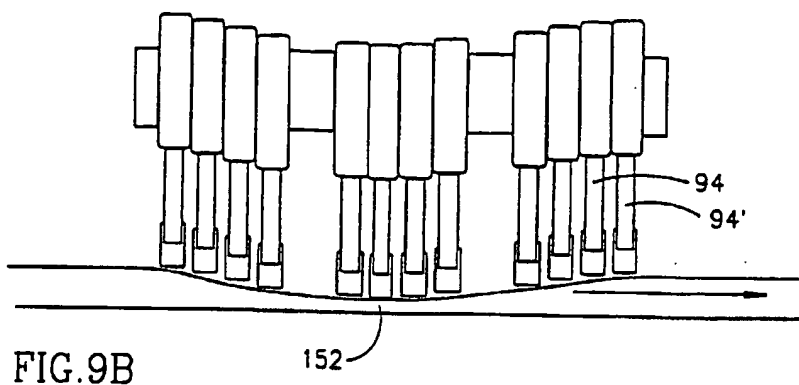
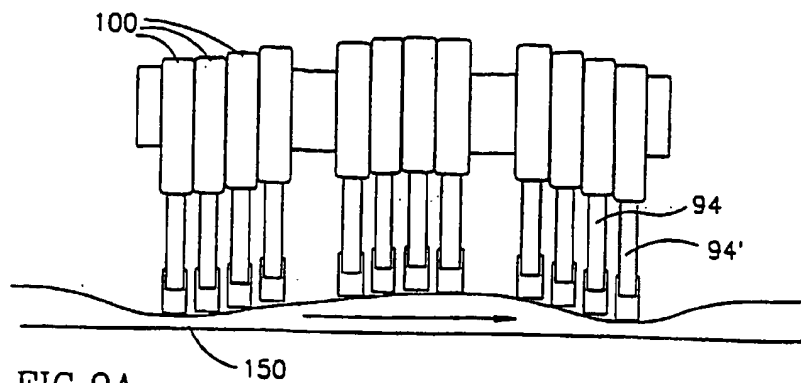


FIG. 8B



**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ BLACK BORDERS
- ☐ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- ☒ FADED TEXT OR DRAWING
- ☒ BLURRED OR ILLEGIBLE TEXT OR DRAWING
- ☐ SKEWED/SLANTED IMAGES
- ☐ COLOR OR BLACK AND WHITE PHOTOGRAPHS
- ☐ GRAY SCALE DOCUMENTS
- ☐ LINES OR MARKS ON ORIGINAL DOCUMENT
- ☐ REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- ☐ OTHER: _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.